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The Art of Military Innovation

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The Art of Military Innovation

Lessons from the Israel Defense Forces

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Introduction

THIS IS NOT A HISTORY OF THE ISRAELI ARMY, NOR A HISTORY OF Israel's wars. It is the record of an investigation that started with a simple question: why is it that the relatively small, relatively poor Israeli armed forces have long been exceptionally innovative?

Decade after decade, both under the urgent pressures of war, but also when threats were quiescent, the Israel Defense Forces (IDF), as officially translated in English, have kept innovating, originally largely by themselves, then in conjunction with the country's nascent military industries and fledgling research centers, both inevitably populated mostly by IDF veterans.[1] Over the years they originated new tactics in the air, at sea, for commando raids, and also for armored warfare—one particular 1973 tank battle was taken up as the model for a successful defense against numerically superior armored forces ("fight outnumbered and win") in subsequent US Army field manuals.[2]

At the higher, operational level of warfare, the Israelis have devised new schemes of combined action, often to take advantage of some new technology because they were so often the early adopters, but sometimes to make the most of entirely conventional forces.[3] In a major 1967 battle, Abu-Agheila/Umm Qatef (June 5–6, 1967), columns of foot infantry, tank battalions, massed field artillery, and descending airborne troops all attacked a well-entrenched, well-armed enemy by converging from different directions—seemingly a recipe for a friendly-fire disaster of epic proportions.

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It was an attempt at a rock, paper, scissors–style synergistic victory: the airborne troops came by helicopter amid the Egyptian artillery batteries, whose crews were of course unprepared for hand-to-hand fighting; and the foot infantry did not attack Egyptian trench lines frontally but instead entered them by first slogging over supposedly impassable sand dunes to reach their unprotected starting points. Meanwhile the tanks, kept at bay by the antitank mines that protected the Egyptian trench lines, nevertheless forced the defenders to keep their heads down by frontal fire and threatened assaults, distracting them from the real threat of the Israeli foot infantry coming down their own trench lines. Instead of a friendly-fire debacle, it was the other side that disintegrated.

The striving to surprise the enemy by novel schemes of action, inevitably by accepting major and sometimes extravagant risks, characterized Israeli operations during the period of major conventional wars, which started in 1967 and ended in 1973 with a cease-fire that evolved into a "peace of the brave" with Egypt in the 1979 Peace Treaty. High-risk tactical innovations were pursued in ways large and also small in many commando operations on land, by sea, and by air. (In one, Super-Frelon helicopters delivered troops and equipment to a distant target beyond their maximum two-way range by returning empty to refuel before going out again to retrieve the soldiers.)[4] The alternative to such risk-taking has always been unacceptable to Israelis: straightforward, low-risk, frontal attacks would have cost tens of thousands of casualties during the years when the IDF fought the largest battles since the Second World War, with tanks and artillery pieces by the thousands, and jet fighters by the hundreds. Lives were saved by bold, risky innovations, not only in small commando raids but also on the largest scale. Perhaps the most extreme example of risk-taking was the assault-crossing of the Suez Canal in October 1973, which violated an elementary principle of war: Israeli forces did not even control their own side of the canal when they crossed over to the Egyptian side to attack the invaders from the rear. Its protagonist, the then divisional commander Ariel Sharon, was duly denounced as a reckless gambler by his colleagues—until he emerged victorious.

But the best-known Israeli innovations were neither tactical nor operational but rather technological, starting in the 1960s with the Gabriel, the West's first antiship missile cheaply developed by the then minuscule Israeli navy, when Israel was still an agricultural country of two million people, with

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little by way of industry, none of it advanced.[5] Arriving in time for the 1973 October war after a rapid development process, the Gabriel decided the outcome at sea by sinking nineteen Egyptian and Syrian vessels, with the loss of none.

That was the first of a sequence of true innovations, or *macroinnovations*, which were not merely new and improved versions of what already existed, but weapons or techniques that did not exist at all until then. In the 1970s macroinnovation was rather micro in form with the first of the small remotely piloted vehicles (RPVs), whose uses have kept expanding ever since, from overhead observation to different forms of attack and even transport; soon renamed unmanned aerial vehicles (UAVs), they then became today's ubiquitous drones. In what has become a global industry, Israel remains an important user and supplier of drones, exporting a variety of models from the smallest hand-launched types to sizeable aircraft that can execute long-range air strikes with significant weaponloads. Also in the 1970s, the Merkava tank was developed in successive versions while remaining the only main battle tank that diverges from the classic rear-engine configuration of every other main battle tank (and at sixty-five metric tons it is the heaviest, and seemingly the best protected).

In June 1982 Israel unveiled the first of a variety of air-launched armed decoys that magnified Israeli airpower, and while a new kind of tactical/strategic submarine is still a project wrapped in secrecy, the Iron Dome antirocket and antimissile system became globally famous in 2014 when it achieved unprecedented intercept rates against ballistic rockets, achieving even better results in the May 2021 fighting between Israel and Hamas in Gaza, when it reduced the impact of some 4,000 bombardment rockets to a handful of casualties. By then the Israeli-developed helmet-mounted display system had become the central innovation of the multiservice, multinational F-35 fighter family (it allows pilots to see right through the aircraft they are flying), while another innovation (not invention), the Trophy active protection system for armored vehicles, detects incoming antitank missiles and rockets with radar and engages them with self-forging munitions.[6] Now integrated with a competing Israeli system (Iron Fist), Trophy has been adopted by the US Army and others for their armored vehicles. In between those major innovations, there were many others, ranging from the reactive armor boxes that can be added to further protect armored vehicles, to the very concept of the

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multirole jet fighter, invented by the Israeli Air Force in the late 1950s when it was still insignificantly small by global standards, and its commanders mere youths.

This remarkable capacity for rapid innovation is facilitated by the peculiar organizational structure of the IDF, and while it is of course propelled by the security imperatives of Israel's situation, another factor is the educational impact of the IDF themselves, as the country's preeminent educational institution. Historically, national armies that conscript all the able bodied and therefore cannot be selective have long functioned as powerful educational institutions, teaching things as basic as personal hygiene and the difference between right and left feet as late as the Second World War in the US Army, along with an increasing variety of noncombat skills, everything from driving motor vehicles to the increasingly advanced use of computers.

That is true of the IDF as well, from the teaching of simple literacy and elementary arithmetic (for social reasons it accepts illiterate and innumerate conscripts) to the funding of advanced postgraduate studies for its officers. But the IDF adds a further element peculiar to itself: an intensely improvisational, can-do culture that can degenerate into overconfidence, but which is exceptionally open to innovation. What that means in practice is that no formal qualifications or position of authority are required to obtain a hearing for a new idea and even development funds if warranted—as quite a few Israelis at large, and some non-Israelis, have discovered over the years.[7]

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[1]

Raising an Army under Fire

FROM THEIR BIRTH IN MAY 1948 THE ISRAEL DEFENSE FORCES (IDF) differed from other armed forces around the world. They were established from the first as a single service, with their fledgling ground, naval, and air units all under the same command, instead of the separate armies, navies, and air forces that existed elsewhere and persist to this day (except for Canada's much later and partly rescinded unification), sometimes with a fourth service, such as the US Marine Corps or Italy's carabinieri.

The IDF were and are also unique in conscripting women as well as men (though with exemptions more easily allowed). They have long relied on women trainers for every skill, including combat training, from the throwing of hand grenades to the firing of rifles, tank gunnery, and the operation of tube and missile artillery. Women therefore perform the combat instructor function prototypically performed by ultramasculine drill sergeant types in other armies. Many women soldiers perform administrative duties indoors, as many are combat trainers. Others have been volunteering to join combat units instead of just training others to fight, and some serve as air force pilots and naval combatants.

Originally, the conscription of women was simply a demographic necessity: a country that started off with a population of some 650,000 Jewish civilians when it was attacked by several Arab countries had to maximize its human resources by conscripting women as well. It was a simple matter of

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assigning as many noncombat tasks as possible to women, to release more men for combat. But over the years, it emerged that women provided not only numbers but also particular abilities, from the reduction of the fear factor in showing new recruits how to perform inherently dangerous actions such as throwing hand grenades, to quasi-maternal patience in imparting skills difficult to learn—both examples of recognizing rather than ignoring gender differences.

Yet another fundamental IDF innovation was inspired by Swiss military practice but carried much further: right from the start the IDF were established as a reserves-centered military force.[1] That was only theory in 1948 because the war started before any recruits had become trained soldiers. These would eventually become reservists, who could be recalled to active duty, but by the time of the 1956 war there were enough former conscripts to staff reserve formations that outnumbered the active-duty units, and that ratio increased further in 1967 and 1973.

That, of course, is the highly desirable advantage of reserve-centered forces: with any given population, they can be much larger than a conventional army staffed only by active-duty personnel. But a much less desirable consequence is that a reserve-centered army must be greatly dependent on advance warning to mobilize the bulk of its forces, a very tricky requirement that not even the best intelligence services can assure.

Of that, the best example was the failure of Israeli military intelligence to predict the October 6, 1973, surprise attacks by Egypt and Syria that were the start of full-scale offensives. In the bitter aftermath, that costly failure was blamed on the individuals in charge of Israeli military intelligence, who failed to revise their certitudes as the enemy forces facing them kept growing. But Israel's dependence on a reserves-centered army set up an impossible task for intelligence: at any given time, if a surprise attack is correctly predicted, the IDF mobilize, and the enemy calls off the attack. At that point, the indicators, both technical and human, including any agents-in-place within the enemy camp, that (correctly) predicted the enemy attack are discredited, while the misleading indicators that denied the danger of a surprise attack are validated. Repeated instances of crying wolf can blind the intelligence system—improving the enemy's ability to achieve surprise on the next occasion.

Exactly that sequence occurred in 1973. There had been indications of a coming war, but none occurred; then in May 1973 there was a large Egyptian

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buildup of forces on the Suez Canal facing the Israeli-held Sinai Peninsula, which triggered a large-scale mobilization of IDF reserve formations and individuals. That shut down much of the Israeli economy at great cost. When no Egyptian attacks materialized day after day, there was the demobilization dilemma: send the reservists home to resume their lives and return to work at the risk that they might have to be recalled to duty again in great confusion, or else wait a while longer as the costs pile up. In other words, a reserve-centered force offers great benefits, and inherent risks. Israel is a democracy—criticism in the media for the "superfluous mobilization" in May was remembered by decision-makers in October, as were American admonitions not to exacerbate the situation. They did not mobilize, and the enemy attacked.

Of all IDF innovations, the single-service structure is perhaps the most important. Its elementary economic advantages are obvious but perhaps not very significant for well-funded armed forces: yes, it is cheaper to have one headquarters structure, one set of uniforms, one set of administrative structures and practices and so on, but the real advantage of unified military forces is that unity favors innovation, as we shall see. Instead of the much-controverted and still-incomplete integration of armies, air forces, and navies that has slowly advanced in the United States as in most countries since the end of the Second World War, the IDF were born united right from the start, with no separate services, and of course no separate civilian ministries with different political ministers in charge. Those ministers, most notably the pre-1947 Secretary of the Navy and Secretary of the Army of the United States, or the British First Lord of the Admiralty, Secretary of State for War, and Secretary of State for Air, as with their equivalents elsewhere, had every reason to oppose the creation of an overall Defense Department or Ministry of Defence, which would make them subordinates of the one minister (or US secretary) of defense.[2]

It was the great predicament of the Jews of Palestine, whose state came under attack as soon as it was proclaimed on May 15, 1948, that they had no armed forces up and running, no army, navy, or air force ready for war to defend the new state. But in subsequent decades, it turned out that there was a hidden advantage in that most dangerous absence of an army, navy, and air force: it enabled the IDF to start anew as a single structure, achieving a unification still unachieved elsewhere.

Military institutions have no value unless they are sufficiently cohesive to generate and sustain the high levels of loyalty and dedication to duty

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necessary to fight in war, but those very same sentiments make military institutions highly resistant to change—and even if change is imposed on them, there may still be reversions as unchanged mentalities reassert themselves to restore what was there before the change. That is what happened with the Canadian Armed Forces—the only ones that tried to adopt the IDF's one-service structure. Until then as separate as their original British models, the Canadian Army, Navy, and Air Force were unified under the 1968 National Defence Act, which firmly stated that "the armed forces of Her Majesty raised by Canada consist of one Service called the Canadian Armed Forces or *Forces Armées Canadienne*."[3]

It was hoped that unification would reduce the cost of socks as they could be bought in one color instead of three, with similar savings across a couple of million other items; and it was hoped that joint war planning and joint command in combat would be much easier if all concerned belonged to the same uniformed fraternity with the same vocabulary, habits, and procedures. The Canadians too had their bitter experiences of combat losses caused by interservice misunderstandings. At first it all worked out for the best with everybody in the same rifle-green uniforms of the unified Canadian Armed Forces. But atavistic identities persisted under the surface, and finally they won out: on August 16, 2011, forty-three years after their unification, the three "environmental" commands of the Canadian Armed Forces reverted to their original names: the Royal Canadian Air Force instead of Air Command, the Royal Canadian Navy instead of Maritime Command, and the Canadian Army (it was never "royal") instead of Land Force Command.

In further deference to tradition, uniforms reverted to their 1968 colors and patterns, complete with dress uniforms in red or blue, gold braid and all the rest.[4] Operationally this reversion is not supposed to mean anything at all, and indeed the separate services have not been formally reinstated—but what happened showed that strong institutional loyalties can override cold cost-benefit calculations, and with good reason: institutional memories and loyalties uphold morale and cohesion (i.e., esprit de corps), the two all-important if nonmeasurable intangibles that differentiate the relatively few armed forces that can actually fight armed enemies from the great majority that can only turn out on parade—and attack unarmed civilians. The issue of separate uniforms is merely symbolic of the truly problematic issues arising from separate weapon-development programs, separate training facilities, and separate, partially duplicative, administrations.

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Institutional memories and institutional loyalties powerful enough to sustain combat morale will also impede innovation just as powerfully, if the particular novelty at hand collides with the missions, status, ethos, or self-images of those involved. That is where the single-service structure of the IDF really makes a difference in favoring innovation, simply because no one-service ethos or self-image stands in the way. Of this the clearest example is Israel's early leadership in unmanned aviation.

While pilots dominated the IDF Air Corps (Heyl Avir) as it then was, as much as pilots dominate almost all air forces, it was not a separate service.[5] Its commanders are subordinate to the single general staff of the IDF, and while pilots might have resisted the introduction of unmanned aircraft, the IDF General Staff did not. It was that organizational factor that allowed Israel to become the world leader in the design, development, and service introduction of unmanned aircraft, starting in 1970, when it was still a relatively poor, industrially undeveloped country of three million in all.[6]

Elsewhere, pilot-dominated air forces efficiently strangled unmanned-aircraft projects, even though the required technologies were so amply available that even toy manufacturers could and did offer remotely piloted aircraft with enough range and payload to be of some military use, right out of the box. Indeed, even now, over half a century later, with all manner of unmanned aircraft flying, including some that are very large and have intercontinental ranges, air forces everywhere continue to resist the adoption of unmanned aircraft (drones) in fighter and bomber roles, striving to reserve them for pilots, while confining unmanned aircraft to less heroic observation roles, except for some missile launches now and then. And that persists even though everyone understands that taking out the humans from the design of combat aircraft can drastically reduce their costs while adding much to their endurance and maneuverability (subtracting discretionary pilot control of course, but that is only important now and then). Because human g-force limits absolutely constrain the design of fighter aircraft, to avoid reversible grey-out, tunnel-effect, and blackout vision incidents, as well as G-LOC descents into unconsciousness and death, fighter aircraft valued for their agility and velocity are severely limited precisely in their agility and velocity by g-force limits that would not bother robotic aircraft at all, if their airframes are mechanically up to the task. In spite of this, not one unmanned fighter-bomber is in production, and even the future US intercontinental-range B-21 Raider heavy bomber meant for the delivery of both nuclear and nonnuclear weapons

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is to be manned as well as optionally unmanned, thereby adding robotic costs to the man-rating and the return-home costs, a very heavy price to pay to allow a few air force officers to pilot those aircraft, a choice that could only have been made by a pilot-dominated air force.

The impediments to innovation caused by otherwise praiseworthy and indeed essential service loyalties seem to affect navies even more than air forces—and that is readily understandable, given their much older origins. And the costs of naval loyalties have steeply increased in recent times, because they motivate the continued development and production of large and very large surface warships, in spite of their ever-increasing vulnerability to all manner of drastically cheaper weapons, including maneuverable reentry vehicles launched by ballistic missiles such as the Chinese DF-21D medium-range and DF-26 intermediate-range missiles, which could destroy any vessel they manage to hit with one descending warhead, including aircraft carriers.

All this was still in the unimaginable future when the State of Israel was inaugurated on May 14, 1948, the fifth day of the month of Iyar of the year 5708 in the Jewish calendar, facing a war already underway without an army, air force, or a navy to resist the armed forces of Egypt, Transjordan, Iraq, and Syria as well as armed bands both small and very large. It was then that the entirely new, single-service IDF was born, as a necessarily original invention because nothing like it existed anywhere in the world.

In the British forces—the ones best known to Palestinian Jews because so many had volunteered to join them during the Second World War—the Royal Navy, the Army, and the Royal Air Force each had its entirely separate administrative, cultural, and even political existence, and indeed differed not only in their appearance but, more profoundly, in their mentalities. Not surprisingly, interservice cooperation was difficult and sometimes simply impossible, and only improved slowly during the long years of war, from disastrous noncommunication at the start in the 1940 Norway Campaign to mere quarreling by 1944, even though Winston Churchill had established the world's first "Minister of Defence" position in 1940—wisely nominating himself for the post.[7] Even so, civil servants and budgets remained with the very separate secretary of state for war, first lord of the admiralty, and secretary of state for air right through the war—in other words, there was a defense minister, Churchill no less, but there was no actual ministry with its own staff or a single ministerial budget. A ministerial staff was provided in 1946, but the three service secretaries remained firmly in control until 1964,

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and it was only then that integration if not unification could begin—with no plans laid down to progress very far down that road.

The British model was therefore irrelevant for the one-service IDF, as was the brand-new American model established by the 1947 National Security Act, which instead of driving service unification, converted the US Army Air Forces into a separate service as the US Air Force, alongside the Army and the Navy, with its increasingly independent Marine Corps. The 1947 Act did also establish a single Department of Defense, but it did not abolish the separate service secretaries, with their secretariats and budgets. Hence successive secretaries of defense and their ever-growing staffs had to strive mightily over the decades to progress toward common planning and purchasing, with research and development even harder to unify.

As for the US structure for military command in war—the essential thing for Israel in 1948 with a war already underway in conditions of potentially catastrophic unpreparedness—it too was divided. The US Joint Chiefs of Staff, belatedly established in 1942 on the model of the British Chiefs of Staff Committee, could at most try to coordinate the separate planning and command of each service, because very literally, there was nobody actually in charge. Its head was neither a commander in chief (that being the president's prerogative) nor an executive chairman—that would only come forty years later with the sweeping 1986 reforms.[8] With no operational staff, and no military officialdom of his own, the first chairman of the Joint Chiefs of Staff, William D. Leahy, had more influence on broad strategy as the president's personal advisor than in the direct conduct of the war, because he had no effective authority over the chief of staff of the US Army, the US Navy's chief of naval operations, or the commanding general of the US Army Air Forces.

There appeared to be no valid model to follow for command structures—the Americans and British themselves kept saying at the time that they had won the war in spite of their command structures, not because of them, while too little was known of the much-admired Red Army.[9] Hence the Israelis of 1948 boldly disregarded all established practice and ignored all traditions to invent their own structure: one service, one general staff, one commander with the title "head of the general staff" (Rosh HaMateh HaKlali) under the immediate authority of the minister of defense, under the overall authority of the prime minister as head of the cabinet, or the cabinet as a whole in the gravest matters. While all other ex-British territories followed the prestigious model of the ever-glorious and newly victorious British armed forces,

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Israel's leaders preferred to leap into the unknown with their own entirely original single-service IDF, a thing never before seen.[10] Thus, the Israelis were the first to venture on the path of service integration that others would follow in their own time, for their own reasons.

One important consequence, easily overlooked because it is a silent absence, is that the IDF never had to strive to harmonize different military services by maintaining joint command headquarters, a process that absorbs energies better used otherwise in perpetual strivings to maintain proper staffing balances between the services and a fair allocation of command slots. In contrast, the IDF have their institutional "jointness" built in, which makes it easier for different kinds of forces to cooperate logistically in peacetime, even if in war the soldiers on the ground, in combat aircraft above them, and in ships offshore will still have entirely different fields of vision, drastically different operational timelines, and weapons whose effective ranges vary from a few hundred line-of-sight meters to thousands of kilometers.

Hence coordinated air-ground fighting still needs much planning and much training, but at least in the IDF such efforts are not impeded by dysfunctional barriers between different institutions. It is to avoid that problem that the US Marine Corps fiercely holds on to its own "air wings" with their Marine-flown fighter squadrons, to provide close air support to Marines fighting on the ground, instead of relying on the US Air Force or indeed Navy pilots for that most difficult task. Even among fellow Marines there is still the need to coordinate different environmental perspectives and timelines, but communications are easier within the same military family and, critically, combat risks are more likely to be shared fairly between Marines above and below, with pilots taking risks to reduce risks on the ground and vice versa. That was famously demonstrated in the Korean War, when vastly outnumbered units of the First Marine Division fought their way south from the Chosin Reservoir from November 27 to December 13, 1950, with Marine pilots ignoring massed machine-gun fire to deliver their munitions with maximum accuracy to support fellow Marines on the ground.

Much the same thing occurred on October 6–10, 1973, when the Israeli Air Force sent its fighter-bombers to attack advancing Syrian forces on the Golan Heights even though they were protected by an abundance of Soviet-supplied antiaircraft missiles that could not be suppressed beforehand. Hugely outnumbered Israeli ground forces were thus able to resist, if only just, at the price of many pilots killed in their destroyed aircraft. As with the Marines,

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there was no institutional separation to diminish the urge of the pilots to help the soldiers on the ground, notwithstanding extreme risk.

Unified Structure and Innovation

When it comes to innovation, the benefits of the IDF's institutional unity are direct, simply because their research and development funds are not parceled out to the separate services that mostly use them to improve existing weapons vehicles and sensors—and especially their iconic platforms, as with the US Army's battle tanks, the US Navy's aircraft carriers and submarines, and the US Air Force's fighter jets and manned bombers. Such incremental innovation, soundly based on the remediation of specific shortcomings that have emerged over the years, or the straightforward replacement of old subsystems with new ones (as when an older jet engine is replaced with a new one that fits in the same volume), is much less risky than macroinnovation—that is, the research and development of something entirely new, which might fail entirely because of irremediable technology gaps, or simply because costs keep increasing with no end in sight.

Moreover, macroinnovation has another and weighty disadvantage: something really new will require the retooling of maintenance facilities and the retraining of their personnel, as well as the training of operating crews *ab initio*, which is costly and time consuming in itself. But macroinnovation offers one very great advantage over incremental innovation that can outweigh all its risks and costs: if the weapon or device is truly new, there will be no countermeasures nor counterweapons already in service with enemy forces to resist, counter, or outmaneuver the new capability. That absence suspends the entire predicament of war that makes it so hard to win battles and wars, namely the existence of opposing forces and opposing minds ready and waiting to observe and negate whatever is attempted.

Such a "countermeasure holiday" occurred on November 20, 1917, the first day of the Battle of Cambrai on the Western Front, when 378 Mark IV tanks of the British Army marked the first appearance of the macroinnovative battle tank in significant numbers. In the absence of antitank guns that had yet to be developed (low-slung guns, with high-velocity rounds to pierce armor), and in the absence of antitank mines—let alone the antitank rockets that came in the next war or the antitank missiles that arrived later still—those 378 Mark IVs flattened the forests of barbed wire that had defeated so many

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infantry assaults, drove right over the trenches that had harbored the riflemen and machine gunners that had previously cut down attacking infantry, and entirely negated both the bullets fired at them and the splinters of artillery shells with their steel-plate armor. Since the introduction to battle of the first tanks a year earlier during the Battle of the Somme, the British attacks had used only a few dozen tanks at any one time, and the Germans had been attempting to develop an antitank response. Of all the countermeasures employed, deploying light cannon to fire directly at the tanks had proven the most effective—and one such antitank battery delayed a British tank force at Cambrai considerably. But the few batteries available at the front could not defeat a massed attack by hundreds of tanks.

That is the reward of macroinnovation, which can win battles, even entire campaigns, if applied on a large-enough scale, by military leaders ready to take the risk of allocating important resources to the new and untried. Mostly they do not, because the really new weapon (as the tank was) will not enhance existing forces, will not affirm an existing way of war.

That is why the introduction of the first machine guns was resisted: none of the existing forces could use them. They were too heavy for the infantry to carry into battle, too clumsy to be mounted on a horse, and too piddling for the artillery that fired powerful explosive shells and not mere bullets. The same was true of the tank, a concept that the British Army refused to invest in, essentially because it threatened to displace the socially dominant horse cavalry and was bound to take away guns from the artillery while overshadowing the infantry. Those being the three branches that controlled the British Army, its leaders refused the idea—and so the first tank was developed by the Royal Navy at the insistence of Winston Churchill.

Simply because the IDF is not a military service or a federation of military services but rather a unified military body, it can accept macroinnovations and fund them, inevitably at the expense of the forces that already exist, because those separate forces with their separate identities are simply not in control. That is the ultimate explanation of the long list of Israeli military innovations. At the very start on May 15, 1948, some 650,000 Jews with a poor agricultural economy and hardly any industry could not develop or manufacture anything that exceeded the scope of a modest number of blacksmithing, welding, and mechanical workshops, with just a few veritable factories, none large, to produce textiles and clothing, canned food, and agricultural hand tools and such.

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But at least the choice of what to develop and manufacture was easy indeed, because all the IDF had at the start were the meager caches of ill-assorted weapons secretly accumulated by the prestate militias, the dominant Haganah and its much smaller rival the Irgun, the result of a 1931 political split. The Haganah ("The Defense") enrolled men and women of all ages in its Heyl HaMishmar (guard corps), fit young people in its Heyl HaSadeh (field corps) and a few thousand in the select Plugot Maḥatz (Palmach—strike units).[11] The much smaller Irgun Tsvai Leumi (National Army Organization) only had a few organized units, while Lohamei Herut Israel (or Lehi; Fighters for the Freedom of Israel), aka the Stern Gang of the poet Yair Stern, did not exceed 300. Aside from odd lots of pistols, revolvers, some submachine guns, rifles of different calibers, shotguns, and a handful of machine guns, there was very little except for some trucks and buses protected with bolted-on steel plates.

The Jews could not legally import any weapons until British rule ended on May 15, 1948, and, because of a UN embargo, neither could their new state import weapons after May 15: even with the invasion of four Arab armies underway, it was nevertheless British policy, vigorously backed by the US government, to stop any weapons at all from reaching the belligerents, ostensibly to limit the violence, but actually to ensure the victory of the invading Arab armies that already had their equipment. That emerges very clearly from the authorized history of the British Secret Intelligence Service.[12] (The doings of intelligence services are rarely very consequential, but they do reflect actual policy aims more accurately than diplomatic declarations.)

Given what had very recently happened to millions of the Jews' coreligionists in Europe, the British stance toward the local Jews was more than harsh, but its motives were not deliberately malevolent. The British were merely being practical: at the time, they still had large military bases in the canal zone of Egypt they meant to keep, and imperial possessions east of Suez. They had trained and equipped the Egyptian Army of King Farouk that was then poised to drive to Tel Aviv; and the British had also funded, trained, and equipped the smaller Arab Legion of the Hashemite Kingdom of Transjordan, commanded by LTG Sir John Bagot Glubb ("Glubb Pasha") and his deputy Norman Oliver Lash, both British citizens, as were the thirty-five officers who commanded the Legion field units that crossed the Jordan to invade Palestine, attack Jewish settlements, and try to conquer Jerusalem.[13]

Iraq, much larger than Jordan and already oil rich, was also ruled by a Hashemite king installed by the British. Its army had also been equipped and

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trained by the British, and its government was dominated by Nuri al-Said, sturdy ally of British interests in Iraq until his murder a decade later.

With all those valuable British assets on one side, and some 650,000 oilless Jews on the other, the British decision to support the Arabs and deny weapons to the new Israeli state was quite rational, as was the decision of the US secretary of state, five-star general, former army chief of staff, and future Nobel Prize winner George Catlett Marshall Jr. to back State Department officials who sided with the British against the White House in believing that President Truman's immediate recognition of Israel on May 15, 1948, was a great mistake that Israel's destruction by victorious Arabs would soon correct.[14] The British foreign secretary Ernest Bevin had already preemptively blamed impractical Zionist dreams for the inevitable massacre of the Jews.

It was therefore very unfortunate that Marshall's tenure (January 1947–January 1949) coincided almost exactly with the most critical phase of Israel's emergence. Though devoid of any personal animosity, let alone antisemitism, Marshall's opposition was absolute and relentless.[15] When Israel's envoy asked for an audience, he refused—he was much too busy with the nascent Cold War to waste any time over an ephemeral ministate that would soon be destroyed.

That was Marshall's prediction as an expert strategist, in which the newly established Central Intelligence Agency (CIA) fully concurred, and one he himself did much to bring about because US diplomats worldwide vigorously joined the British in preventing any weapons at all from reaching Israel.[16] Europe was then still littered with abandoned but still very usable weapons of all kinds, in all sorts of depots or under tarpaulins in the open, everything from rifles, artillery, and tanks to functioning or repairable combat aircraft. And Europe's impoverished postwar governments would eagerly have sold any weapons they had to the new Israeli state, which from May 15, 1948, had the legal right to buy anything it wanted. But as soon as word of a sale reached them, British and US diplomats would intervene, with their then-immense prestige, successfully in all cases but one: Czechoslovakia, a small country with world-famous small-arms factories eager for business.

That was indeed important because the newborn state could not hope to equip effective armed forces with the odds and ends that smugglers brought in—small batches of weapons of different calibers, often old and worn out, or missing parts. Nor could smugglers hope to bring in combat aircraft, armored vehicles, or field artillery—all too big to pass undetected. So extreme

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was the need for weapons once the Arab invasions started on May 15, 1948, that two antique French 65 mm howitzers (Canon de 65 M model 1906) with missing sights, which fired feeble ten-pound (4.4 kg) shells at a leisurely 330 m/s muzzle velocity, were viewed as weapons of strategic importance reserved for the highest-priority tasks, starting with the defense of the Degania sector on the Jordan River against the invading Syrian army on May 15–21, 1948.

Marshall's expert prediction might well have proven accurate had it not been for the coalition government of Czechoslovakia, which ignored Anglo-American pressures and sold weapons to Israel from its extensive stocks of weapons, both those produced by its sizeable and innovative military industries before 1938, and those produced under wartime Nazi direction thereafter.[17] Soon chartered transport aircraft flown by intrepid volunteer pilots delivered 34,500 German Mauser rifles that Israelis still call Czehi, along with 5,515 MG 34 medium machine guns, 500 ZGB 33 light machine guns, 900 ZB 53 medium machine guns, and more than a million rounds of ammunition.

The Czechs also had fighter aircraft to sell, sixty-one British-made Spitfire Mk IXs that had equipped the Free Czechoslovak Air Force squadrons of the Royal Air Force and were still first-line aircraft in 1948, and twenty-five locally made Messerschmitt Bf 109s (reuniting both protagonists of the Battle of Britain) and more dubious Avia S-199s.[18] In addition, the Czechs provided training for eighty-one pilots and sixty-nine ground crew, as well as an airfield for the transshipments to Israel. It was not much as compared to the inventories of the Arab armies, and it was impossible to airlift any of the locally plentiful armored vehicles in light transport aircraft, but the Czech shipments were enough to make all the difference by providing homogenous sets of small arms for IDF field units, leaving the odds and ends accumulated over the years for the local-defense units.

Not all the fighter aircraft survived the perilous transit (only possible at all because of a secret refueling airstrip made available by Tito's Yugoslav government), but enough did to allow courageous pilots to immediately go over to the offensive against the Egyptian Air Force. Equipped and trained by the British over the years, the Egyptians had already bombed Tel Aviv's central bus station on May 18, 1948, killing forty-one and wounding sixty, to this day a greater casualty toll than any subsequent Arab air attack in seven decades of intermittent wars.[19]

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All-important as they were, the Czech shipments did not include any artillery or armored vehicles, both of which were essential to resist the invading Arab forces and then to go over to the offensive. That is how Israel's history of military research and development started, prompted by necessity rather than technological ambitions, with novel designs imposed by very severe technological limitations rather than any striving for originality for its own sake.

The Davidka mortar, the very first Israeli weapon developed from scratch, exemplified both characteristics. Three-inch mortars (actually 3.209 inches/81.5 mm) were standard in the British Army, and the Davidka too had a base plate and a three-inch tube. But there was no available supply of three-inch bombs, and none could be produced in local workshops with the precision needed to avoid deadly in-tube explosions. The highly original solution was to make supercaliber bombs with a caliber-sized rod to propel them that could be safely projected from the mortar's barrel. With four times as much explosive as British three-inch mortar bombs, the Davidka made for very loud explosions, but lacking in both accuracy and range, it was more useful to frighten enemies than to attack their defenses. Only seven were made and they achieved little. As for armored vehicles, aside from two medium Cromwell tanks stolen by sympathetic British Army drivers during the final British withdrawal, and three defective US M4 Sherman tanks assembled from assorted wrecks left behind by the British Army, there were only improvised armored vehicles, made by bolting steel plates with firing slits onto trucks or buses, some with frontal rams to break through obstacles.

There was also an early anticipation of today's compound armor in the use of plywood, concrete, rubber, and even glass plate sandwiched between thin metal sheets. The different densities served to deflect bullets, while limiting total weight to avoid overtaxing engines and overloading chassis. But as soon as standard face-hardened steel plate could be imported, it was much preferred.[20]

Jeeps could not be armored but they could be armed, and the IDF equipped some with the formidable firepower of two MG 34/41 machine guns each firing 1,200 rounds per minute—ideal for fast raiding by providing short bursts of very intense fire to intimidate and suppress resistance. They equipped the Eighty-Ninth Commando Battalion formed and initially led by the subsequent general, chief of staff, and minister of defense Moshe Dayan, who was notably successful in gaining territory by hit-and-run raids.[21]

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The jeeps arrived because even the otherwise very effective Anglo-American embargo could not prevent the import of entirely unarmed vehicles from the war-surplus dumps in Europe, even if they had originally been military vehicles. That category included thinly armored ten-ton US-made M-3 half-tracks that combined front wheels for steering with tracks in the rear for propulsion, and a protected front cabin with an open-topped rear cargo volume. They were to have a very long life in the IDF: while the US Army replaced all its half-tracks with fully tracked vehicles just as soon as it could, the IDF still used many in the 1982 Lebanon war, and some remained in use for another decade beyond that.

More than 3,000 half-tracks were imported by the IDF over the years, initially to serve as armored troop carriers but later adapted for many specialized roles: as command carriers with extra radios and a front winch; as weapon carriers for heavy machine guns, for 81 mm mortars, for locally made heavy 120 mm mortars, for twin 20 mm Hispano-Suiza HS.404 cannon, for rockets and mine-clearing Bengalore torpedoes, and finally for antitank missiles; and as combat-engineer vehicles, ambulances, and more. Half-tracks were modified for all these different purposes because they were cheap and abundant as compared to any other armored vehicle, and because the open-topped cargo area could readily be modified to accommodate weapon mounts or anything else, including armored cabins for the evacuation of the wounded. What happened with this particular vehicle through all its different modifications illustrates a fundamental aspect of IDF culture that persists vigorously even decades after the arrival of their first new weapons, delivered complete with replacement parts and specific maintenance tools: a proclivity for rehabilitating secondhand military equipment acquired in varied stages of disrepair, by repairing, retrofitting, and modifying what arrived till it becomes useful, either for the purposes originally intended, or for something else entirely.

During the years of large-scale wars from 1967 to 1973, the rewards of this proclivity were very substantial, indeed of strategic significance, because the IDF's arsenal was substantially reinforced with weapons captured on the battlefield. Thus US-made M48 Patton main battle tanks captured from the Jordanians were added to Israel's M48s originally delivered by West Germany when its army was reequipped with much more modern Leopard tanks. Over time, both were upgraded with new 105 mm guns and eventually reengined with powerful diesels in place of their original gasoline engines that caught

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fire all too easily. With those changes, Israel's M48s were almost as good as the newest M60s, which the IDF only acquired much later.

Many of the Soviet T-54/T-55 tanks captured in 1967 were cannibalized and repaired as necessary to equip new tank units, and then over time they were successively upgraded with new 105 mm guns, coaxial machine guns, radios, and sundry bits and pieces as the Tiran series of recycled tanks. With fewer or no modifications, excellent Soviet small arms, including the justly celebrated AK-47, were also transformed from battlefield loot into properly maintainable weapons that armed entire units, a process which was replicated with captured Soviet artillery, and particularly the 130 mm long-range gun.

The recycling of captured Soviet tanks acquired strategic importance because it allowed the IDF to keep up with the rapid post-1967 expansion of the Egyptian, Syrian, and Iraqi armored forces, at a time when the United States was only manufacturing thirty Patton M60s per month, and the United Kingdom offered its Chieftain tanks (initially codeveloped with Israel!) only to Iran and to Arab armies. In October 1973, Soviet antitank missiles and rocket-propelled grenades (RPGs) in huge numbers allowed brave Egyptian infantry troops to engage oncoming Israeli tanks, destroying some and immobilizing many more, to the point that Israel's armored forces were visibly shrinking just as Iraqi armored forces were arriving to join the fight. It was the Tirans as well as other captured Soviet tanks that allowed the IDF to achieve the organizational miracle of fielding a new armored division in ten days, with tank crews and all other essential personnel found by recalling older reservists, quickly retraining tank crews that had lost their tanks, and combing out armor and other combat soldiers who had drifted into administrative tasks.

The can-do, improvisational mentality originally instilled by the compelling necessity of rehabilitating abandoned equipment—everything from small arms to multiengine aircraft—by repairing, refitting, and retrofitting, has persisted through the decades even as the country acquired increasingly advanced laboratories and factories. It is manifest chiefly in a willingness to act quickly, accepting risks along the way—the exact opposite of the zero-risks mentality that slows weapon development to a glacial pace in Europe and the United States.

These days, with Israel sufficiently advanced to sell sophisticated weapons around the world, it must accept drastically different US methods when developing, producing, and modifying equipment for the United States. Shaped

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by countless regulations mandated by the US Congress in order to combat "waste, fraud, and mismanagement" in military procurement, the process is declaredly adversarial in imposing exhaustive documentation at each step, and "objective" testing: instead of quickly making proof-of-concept prototypes and testing them to uncover deficiencies that can quickly be fixed before the next test, engineers must take all the time needed—years sometimes—to perfect what they make even in the prototype stage, because it is tested by an outside test and evaluation entity that earns its keep by finding faults. They take their time to test exhaustively, covering all the just-in case possibilities in all weathers and all conditions, and then take more time to compile their reports.

It is only then that the development process can resume after any test failure—unless the project is cancelled on the basis of the report. Thus for example the United States remained without remotely piloted surveillance aircraft till Israeli ones were purchased in time for the 1991 Gulf War because the US-designed Lockheed MQM-105 Aquila, whose development started in 1972, was suspended in September 1985 (after thirteen years!) because the system failed 21 of 149 performance specifications, a number that itself proves frivolous excess in mandating outlandish requirements.

The phenomenal rapidity of the development of the Iron Dome antirocket system, from its first funding in 2007 through research and development, tooling and production, training, and deployment to its first successful combat use in April 2011, shows that the IDF's high-speed innovation culture is still in good working order: four years to develop a new missile is unheard of, but in this case there was also the extraordinary software that makes all the difference by only launching interceptor missiles against rockets projected to hit people or very valuable objects. That same example shows that the other innovation inheritance of 1948 is also still in place, because the phenomenally successful Iron Dome was not developed by the ground forces or the air force or the navy—none of which has its own research and development organization—but rather by the one and only research and development organization that serves the IDF as a whole.[22] That was just as well because the Iron Dome would never have been developed by ground-force officers who naturally prioritize the development of armored vehicles and other ground weapons, or naval officers with surface and submarine warfare on their minds, or by airmen whose solution for every problem is offensive airpower. Anything really new is unlikely to fit comfortably within existing

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service roles, so the necessary effort to research and develop the really new and bring it to operational status is unlikely to be forthcoming, as the chiefs of each service focus on their own priorities.

What would have happened to the Iron Dome in the absence of the one-service IDF is what actually *did* happen with the nondevelopment of US military space satellites, whose critical importance for the US Army, Navy, Marine Corps, and Air Force has never been disputed, but which none of the above was willing to develop with its own budgeted funds, preferring to use their funds to ameliorate their existing equipment. And this went on until the Soviet Union launched Sputnik, the first artificial Earth satellite, into an elliptical low-Earth orbit on October 4, 1957, inflicting a colossal shock. This did not happen with the Iron Dome because Israel's military research and development funds are not preallocated to different branches of the armed forces and can be spent on macroinnovations that, being entirely new, do not yet have service advocates. Instead of falling between service cracks, once their potential is recognized, macroinnovations can obtain proof of concept funding, and from then on, if a new capability is indeed demonstrated, the project can advance to production and deployment. That is the only way truly large advances can be achieved, because really new equipment is not constrained by the design limits of prior equipment and—much more important—it can benefit from a "countermeasure holiday" before adversaries can react with their technical, tactical, or operational countermeasures. It is for that reason above all that *macroinnovation* can be very important in a strategic competition: it offers new capabilities in their pristine state before they are countermeasured, and on occasion those capabilities can be decisive in war, or even in peace, that is, by forcing adversaries to redirect resources from other tasks to the countermeasures against the macroinnovation.

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